NUCLEAR POWER SYSTEMS:

THEIR SAFETY

Current Issue Review

83-14E

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Revised 1 August 1996

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Canada Communication Group -- Publishing
Ottawa, Canada K1A 0S9

Catalogue No. YM32-1/83-14-1996-08E
ISBN 0-660-16747-6

N.B. Any substantive changes in this publication which have been made since the preceding issue are indicated in **bold print.**

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ISSUE DEFINITION

Human beings utilize energy in many forms and from a variety of sources. A number of countries have chosen nuclear-electric generation as a component of their energy systems. **By mid-1996, there were 447 power reactors operating in 31 countries, accounting for more than 15% of the world's production of electricity. In 1996, 18 countries derived at least 25% of their electricity from nuclear units, with Lithuania leading at just over 76%, followed closely by France at 75%. In the same year, Canada produced about 19% of its electricity from nuclear units. Six new reactors were added to the grid between June 1995 and June 1996 - two in Japan, and one each in Ukraine, South Korea and the United States. Two other reactors, which had been shut down for some time, were reconnected in the last year. Brown's Ferry 3 in the United States had been closed since 1985 and Armenia 2 had been out of service since 1988. One reactor in Germany and one in Canada (Bruce 2) were closed. In the same year, 39 power reactors were under construction in 15 countries.** No human endeavour carries the guarantee of perfect safety and the question of whether or not nuclear-electric generation represents an "acceptable" risk to society has long been vigorously debated.

Until the events of late April 1986 in the then Soviet Union, nuclear safety had indeed been an issue for discussion, for some concern, but not for alarm. The accident at the Chernobyl reactor irrevocably changed all that. This disaster brought the matter of nuclear safety into the public mind in a dramatic fashion. Subsequent opening of the ex-Soviet nuclear power

* The original version of this Current Issue Review was published in October 1983; the paper has been regularly updated since that time.

program to outside scrutiny has done little to calm people's concerns about the safety of nuclear power in that part of the world. **In addition, nuclear reactors in all parts of the world are aging, raising still more safety concerns.** This paper discusses the issue of safety in complex energy systems and provides brief accounts of some of the most serious reactor accidents that have occurred to date, as well as more recent, less dramatic events touching on the safety issue.

BACKGROUND AND ANALYSIS

A. Safety in Complex Energy Systems

Assessing how complex systems fail is a complicated matter and recent reactor accidents have demonstrated that this assessment is less certain than formerly supposed. Not only may complex systems incorporate errors in design, contributing to safety problems, but they may also suffer from improper construction, quality assurance, maintenance and operation.

The reactor accident of March 1979 at the Three Mile Island generating station in Pennsylvania illustrates how mechanical problems can be compounded by operator error, emphasizing the importance of human reliability as well as equipment reliability in ensuring safety. Indeed, the Report of the President's Commission on the Accident at Three Mile Island (the "Kemeny Report") had more to say about the people involved in reactor safety -- the equipment manufacturers, the utility managers, the plant operators and the staff of the U.S. Nuclear Regulatory Commission (NRC) -- than it did about improving the technology.

Accidents may also occur because supposedly independent and redundant systems fail simultaneously due to a common initiating event. For example, identical valves in independent units have failed simultaneously in response to a common set of conditions because they were not designed or installed properly. Improper maintenance may also cause a common failure, perhaps because each of the independent units has been improperly calibrated or serviced. A totally unexpected failure may also occur because the sheer complexity of the system has prevented all potential accidents from being identified.

The Salem-1 reactor in New Jersey provides an example of an unanticipated failure. When a routine anomaly or "transient" occurs during reactor operation, a safety system is supposed to automatically shut down or "scram" the reactor by stopping the nuclear chain reaction.

A failure of the safety system to so operate -- termed an Anticipated Transient Without Scram (ATWS) -- was supposed to have such a low probability of occurrence that the risk it represented was considered negligible. The U.S. nuclear industry argued that ATWS regulations and protective measures were unwarranted on the grounds that the basic safety systems were virtually fail-safe, and an expert on reactor safety could write in 1980: "No reactor has ever failed to 'scram' in an emergency." Yet twice within four days, in February of 1983, just such an event occurred at Salem-1. Operators manually scrammed the reactor in both cases, preventing damage to it, but the incidents demonstrated that a breakdown in electronic safety systems was not as implausible as the industry had maintained.

The subsequent investigation of the Salem-1 incident by the U.S. NRC determined that a critical component, designed to drop the reactor shut-off rods automatically, had failed in both circuits of a doubly redundant system. This component, which should have received twice-yearly maintenance, had not been maintained at all during its years of service in the station and "dirt accumulation on exposed linkages" was described by the NRC as one of the causes of failure.

The Chernobyl accident, the worst-ever accident involving a commercial nuclear power reactor, resulted from an incredible series of "human" errors. It is interesting to note, however, that an article in a Kiev newspaper, a month before the accident, had criticized acute shortcomings in materials, shoddy workmanship and low morale at the plant.

This accident has sparked an unprecedented interest in the question of nuclear safety and as a direct result the International Atomic Energy Agency (IAEA) developed two new international conventions. Canada has signed both of them; the first deals with early notification to other countries about nuclear accidents and the second involves an undertaking to help other countries which have suffered such an accident. The IAEA has also received proposals involving international regulation of nuclear power.

In the United States, the growing number of serious operating mishaps at nuclear power installations led that country's Nuclear Regulatory Commission to make the chilling prediction that, given the level of safety being achieved by the operating nuclear power plants in the U.S., one could reasonably expect to see a core meltdown accident within the next 20 years.

Moreover, it is possible that this accident could result in off-site releases of radiation as large as, or larger than, the releases estimated to have occurred as a result of the Chernobyl accident.

Increased interest in the study of nuclear safety resulted from events at Three Mile Island and Chernobyl. The United States Nuclear Regulatory Commission began implementing its Severe Accident Policy in 1985. As part of that new program, all existing plants were systematically examined for severe accident vulnerability and mitigative measures were suggested where necessary. As reactors in the U.S. age, it is becoming more difficult for them to meet the higher standards and it is often too expensive for the companies involved to make the necessary repairs. Thus, more and more reactors are being taken out of service as time goes by. **The re-start of the Brown's Ferry unit this year is an exception to the trend.**

Canada also carried out a major internal review of its nuclear power plant safety. In addition, the Operational Safety Review Team (OSART) of the International Atomic Energy Agency was invited to review operating practices at the Pickering Nuclear Generating Station. Results of both studies indicated that the CANDU reactor was being operated safely in Canada, although minor changes to operating procedures and emergency plans were suggested. **Despite this reassurance, however, a leak of 150,000 litres of radioactive water occurred at the Pickering station in late 1994. In reviewing the accident, the Atomic Energy Control Board reported that, in addition to a fundamental design flaw with the pressure relief valves, human error had contributed to the severity of the spill. The AECB itself came under criticism because engineers at Pickering could not reach Board staff during the crisis.**

West Germany has carried out a major study of nuclear power plant risks. The study concluded that the consequences of severe accidents at German light-water reactors would be lower than previously estimated, by one to two orders of magnitude. Despite this very reassuring result, the Germans instituted a plan to install a new safety feature on all existing pressurized water reactors. This feature involves a filtration system which allows for controlled depressurization of the containment structure. This measure is designed to prevent the build up of potentially explosive amounts of gas in the containment building during a serious accident, in an attempt to avoid

endangering the public. When East and West Germany were reunited, safety concerns prompted the immediate closure of the five Soviet-built reactors at Greisfeld in former East Germany.

In France, a report by the chief inspector for nuclear safety noted that, given the current (early 1990s) state of reactors operating in France, the chances of such an accident happening in the next 20 years amount to "several percent." The potential for human error, which was responsible for the Chernobyl disaster, is cited as the main reason for such an alarming risk of a nuclear disaster. The report goes on to cite several previously unreported "near-accidents" at French reactor sites which could have led to large releases of radioactivity if not stopped in time.

Since the accident at Chernobyl, the international community has been heavily involved in helping Ukraine and other countries with RBMK-type reactors find technically and financially feasible ways of improving safety. This is an important step in the short term, but for the countries involved, the ultimate goal is to close down the four reactors at Chernobyl and provide the financial assistance necessary for Ukraine to construct new power plants to replace the electricity currently provided by Chernobyl. In late 1995, an agreement to accomplish these tasks was reached, with the international community pledging $32 million in aid to Ukraine. Canada was instrumental in the successful negotiation of the arrangement and will contribute $3.2 million.

B. Inherent Safety vs. Engineered Safety

The safety of most commercial nuclear reactors in operation today depends on engineered systems. In the event of an accident, some engineered systems must detect danger and then respond to it in order to shut down the reactor. It is also possible and perhaps, in light of the Chernobyl accident, essential to design reactors that are "inherently" safe. The shutdown of such reactors during an accident would rely solely on the laws of physics and not on engineered systems and operator intervention. In the words of one writer, "The idea behind inherent safety is to replace Murphy's law (if anything can go wrong, it will) with the laws of physics." Several countries have been developing inherently safe reactors and they will serve as illustrations of the concept.

Sweden has developed a pressurized water reactor it calls PIUS, in which the core cooling system and all heat exchangers are immersed in a solution of boron. Boron is a neutron absorber and quickly damps down the heat-generating chain reaction. During normal operation, the pressure generated by the coolant pump keeps the borated water out of the reactor. If the coolant pumping system fails, the difference in density between the hot water and cold water would immediately cause the reactor to be flooded with borated water, shutting down the chain reaction. No human, mechanical or electrical intervention would be required to achieve shutdown. **Sweden is moving away from using nuclear power and so no commercial PIUS reactors have been built.**

Germany has a high-temperature, gas-cooled reactor (called the THTR 300) which has round fuel elements the size of tennis balls. These fuel elements are circulated: one drops out of the core every eight seconds and another is put in on top. Because of the size and surface-to-volume ratio of the fuel elements, it is impossible for the core temperature to exceed 1600°C. The designers claim that this reactor could lose all of its coolant (helium gas) without getting hot enough to release fission products.

A number of reactors being worked on in the United States also incorporate self-shutdown mechanisms that require no mechanical, electrical or human intervention. Since the accident at Chernobyl, such reactors are much more attractive than they once might have been. In the U.S., in fact, observers believe that the introduction of such reactors is the only way in which that country will again accept nuclear power as a viable energy supply option. **The economics of power generation in the U.S. have brought new construction of nuclear plants to a standstill in that country. No new plants, of either the old or new design, are currently on order.**

C. The Chernobyl Accident

On 26 April 1986, the town of Chernobyl, located 60 miles north of the Ukrainian capital of Kiev, became the site of the most serious accident ever known to have taken place in a nuclear power reactor. A series of human errors, combined with what some western experts believe to be serious design flaws, resulted in a catastrophic explosion and fire involving the core of

the reactor itself. The immediate results of the explosion and fire were the death of two people on the site and a very large release of radioactivity. The unprecedented release of dangerous fission products from the reactor core necessitated the evacuation of tens of thousands of people, and contaminated an area of approximately 300 square kilometres of rich farmland. The radiation spread across international boundaries, contaminating food and causing much concern over long term health and environmental effects.

On 25 August 1986, the Soviet Union presented a detailed report on the causes of the Chernobyl disaster at a special meeting of the International Atomic Energy Agency (IAEA) in Vienna. Ironically, the most serious nuclear reactor accident of all time occurred in the course of a safety test. Apparently workers were trying to determine how long the turbine generators would continue to turn due to inertia in the event of an unplanned reactor shutdown. To carry out this experiment, the workers committed no less than six serious errors - including shutting off all the reactor's automatic safety systems so that they would not interfere with the experiment.

The chain of events started on 25 April, when the power level in the reactor was reduced. Because automatic control systems were in place to prevent the reactor's operation at such low levels, the workers shut them off. This removed one of the safety systems designed to prevent the reactor from going out of control. Power levels then dropped too low for the test, and in trying to bring the reactor back up to the required level, technicians committed the second fatal error. Control rods are used to regulate and, as the name implies, control the chain reaction in the reactor. In the light-water-cooled, graphite-moderated (RBMK in Russian terminology) design there must be a minimum of 30 control rods inserted in the reactor at all times. Technicians at Chernobyl removed all but six to eight of the rods. To compound the problem, a second safety system, which would have automatically shut down the reactor when the turbines stopped, was also disconnected for the test.

The actual test started at 1:23 a.m. on 26 April when power to the turbine was stopped. Just before this was done, the flow of water to cool the reactor was reduced and safety devices that would shut down the reactor in the event of abnormal steam pressure or water levels were disengaged. This latest manoeuvre caused the reactor to start overheating dangerously, but,

because the emergency cooling system had been shut down 12 hours before, there was no relief from the heat buildup. Within seconds, a tremendous power surge caused two explosions which blew the roof off the reactor building and ignited over 30 fires around the plant. The damaged reactor core and the surrounding graphite moderator started burning at temperatures up to 1600°C. The fire burned for 12 days, releasing massive amounts of radiation into the atmosphere.

Exactly how much radioactivity was released is not yet known, but there have been numerous estimates. One U.S. estimate holds that at least 40 million curies of radioactivity were released; this compares well with the Soviet estimate of 50 million curies noted in their report to the IAEA. This represents about 3.5% of the radioactivity of the core. (By comparison the Three Mile Island accident in the United States released only 15 curies of Iodine-131.) While it is hard to compare this release with that of Hiroshima or Nagasaki, because the fission products involved are different, one radiation physics expert says that, roughly speaking, the Chernobyl accident released an equivalent of 30 to 40 times the radiation of those atomic bombs.

Much of the radiation fell on the plant site and surrounding towns and farms, but some was carried into several neighbouring countries, including Sweden, Poland, Romania, Switzerland, West Germany and Yugoslavia. In these countries, radiation levels temporarily increased to several times normal levels. In the town of Chernobyl, 12 miles from the site of the accident, a maximum radiation of 15 millirems/hour was reported. Normal background radiation in most parts of the world is about 0.01 millirems/hour.

In economic terms, the accident has been a disaster for the former Soviet Union and the newly independent states of Ukraine and Belarus, which have inherited the problem. In addition to the cost of resettling 135,000 people, they face the loss of the $1.9 billion plant itself, a cleanup bill in the hundreds of millions of dollars and the loss of much needed nuclear generating capacity. This potential loss of electrical production was so serious, in fact, that in October 1986 Units 1 and 2 at Chernobyl were restarted. Unit 3, which shares a control room and generating equipment with the unit destroyed in the accident, was restarted in the early part of 1988. **As noted previously, the international community has recently (December 1995) moved to provide financial assistance to Ukraine so that, by the year 2000, all four units at Chernobyl can be closed.**

On top of these costs comes the cost of improving safety standards for all RBMK reactors in the former Soviet Union. Measures being instituted include an increased number of absorbers, higher enrichment of fuel, control rod modifications and improvements in the protection against human error in the early stages of an accident (i.e., more automation).

The affected countries of the former Soviet Union also face the loss of much valuable farmland and the associated loss of agricultural production. For example, Belarus has lost 20% of its farmland as a result of the disaster. One American study done soon after the accident put its total cost to the economy of the former Soviet Union at $3.7 to $6 billion (U.S.). The Soviets themselves admitted to direct losses of some $3.6 billion (U.S.) at that time. More recently, however, other authorities have estimated that some $200 billion rubles ($380 billion Cdn.) would be required over the next 10 years to cope with the consequences of the Chernobyl disaster. Whatever the final figure turns out to be, it will represent an enormous drain on the economy of the whole region.

The immediate health effects of the Chernobyl accident were not difficult to assess. At the time 31 people were reported to have died as a result of the explosion and subsequent release of radioactivity. About 300 or so other people were treated for acute radiation sickness but were later released from hospital. A newspaper article from November 1989, however, noted that the death toll from the accident had already reached 250 people.

As for the long-term health effects of Chernobyl, the picture becomes much more clouded and there is debate over how many people will be affected. The most widely reported estimates vary from 2,000 to 6,500. That is to say that experts expect anywhere from 2,000 to 6,500 extra cancer deaths over the next 50 to 70 years as a result of Chernobyl. Other experts have expressed the fear that this number could be much higher -- as high as 50,000 to 250,000 -- due to the possible contamination of the food chain by caesium 137 and caesium 134. Caesium lodges in tissue and in muscle and delivers a large dose of radiation to those who absorb it. The absorption of radioactive iodine, especially in children, is also of grave concern.

Five years after the accident, the incidence of thyroid cancer in children in the areas that received the highest levels of contamination had already begun to rise dramatically. Doctors in

the region admitted that, of the children being monitored, 14% suffered very heavy doses of radiation; however, fully 40-45% are now showing enlarged thyroids. This symptom is a known precursor to thyroid cancer. **By 1996, 10 years after the disaster, these fears are being realized. A recent report indicates that the rate of thyroid cancers in the most contaminated areas has shot up from one per million before 1986 to 200 per million in 1994.**

Authorities note, with considerable pessimism, that thyroid cancer and leukemia are usually just the first types of cancer to show up. **The experiences of Japanese survivors of nuclear bombs had, however, led experts to expect that cases of leukemia would be the first to increase. So far there has been no noticeable increase in the number of leukemia cases near the Chernobyl site. This is probably due to differences in the nature of the radiation and the susceptibility of the exposed population.**

In addition to cancer deaths, the damage that radiation can do to the human immune system is expected to result in an increase in all types of infectious diseases during the coming years. **Fetal exposure to high levels of radiation exposure has also been linked to higher than normal occurrences of mental retardation, and emotional and behavioural disorders.**

The social and political fallout from the Chernobyl accident threatens to be as long-lived as the radioactivity it released. Late in 1990, a further 73,000 people were moved out of areas of the Ukraine, Belarus and Russia that are now considered to have unacceptably high levels of radiation. There are reportedly plans to relocate still another 300,000 people eventually. These figures are in addition to the 100,000 people who were moved out of the area in 1986.

D. Recent Issues of Concern

1. Aging Problems in East European Reactors

Recent political changes in eastern Europe have led to a greater awareness of the state of the nuclear reactors in that part of the world. This new awareness has brought a great deal of concern. Most of the reactors in eastern Europe are a Soviet design and are in urgent need of repair and/or upgrading. Following the reunification of Germany, five such reactors in East

Germany were shut down because they did not meet West German safety standards. In other countries, such as Czechoslovakia and Bulgaria, the need for the power from the "dangerously antiquated" nuclear reactors is such that shutting them down is not an option. The international community has stepped in to help with upgrading the safety features, both operational and mechanical, of those Soviet-designed reactors deemed to be safe enough to be worth upgrading. The G-7 has set up a multilateral fund which started at \$74m (US) in January 1993 and is hoped will ultimately total some \$700m (US), the amount believed needed to accomplish the necessary work. The fund will be administered by the European Bank for Reconstruction and Development.

In addition, the European Community has two programs in place to help identify and address safety issues in Soviet-designed reactors. These programs, known as TACIS and PHARE, are set up in such a way that they complement rather than duplicate the G-7 program.

Despite international efforts to date, concern remains high. In late 1995, for example, a report by Russia's official inspection body indicated that nuclear safety in that country was plummeting. More than 38,000 safety violations were recorded at civilian and military establishments in the two preceding years. The report cited the continued operation of dangerous reactors and poor radiation protection as two of the leading causes of this state of affairs.

The announcement in mid-1995 that Armenia, facing a desperate need for electricity, would be re-starting its aging nuclear power plant has caused great concern, particularly in Europe. This plant was closed as a precaution as a result of damage it suffered in the devastating earthquake in the region in 1988. The area is very prone to such quakes and neighbouring countries fear a breach of containment, since the plant is not designed or built to withstand them.

2. Accident at Japanese Nuclear Generating Station: February 1991

On 9 February 1991, an accident occurred in one of the three 500 megawatt, pressurized water reactors at the Mihama plant site. Mihama is 365 km west of Tokyo. An initial assessment of the incident indicated that the problem was discovered when technicians found

abnormally high levels of radioactivity in the reactor's secondary cooling system. This was likely caused by the rupture of a pipe allowing radioactive water to flow into this part of the reactor. As soon as the problem was discovered, operators at the plant began to reduce power in the reactor as a first step in shutting it down. Approximately ten minutes after the event began, and while operators were manually reducing the power level, the emergency core cooling system was triggered. This system functioned as it was supposed to and the reactor, which is based on a Westinghouse design, was brought safely to a shut-down condition. Radiation monitoring devices at the plant perimeter did not register any unusual levels of radiation, leading authorities to conclude that the accident released no radiation into the environment.

3. Higher Than Expected Tritium Levels Near Pickering: February 1991

Information showing an eighty-fold increase in tritium levels near the Pickering Nuclear Generating Station between 1986 and 1989 was made public on 19 February 1991. The Ontario Ministry of Environment was carrying out measurements that would provide background data to authorities in case of a major accident, when the discovery was made. Ontario Hydro and the Atomic Energy Control Board have commented that, although these results indicate that levels have risen considerably, even these relatively high tritium levels are well within safe limits for human health. It is also noted that tritium has a very short half-life and that if the ministry had returned to the same sites an hour or two later, levels would have dropped again to near normal background levels. Hydro officials have commented that their regular monitoring has not picked up this increase in tritium levels and suggest that it is possible that the measurements were taken shortly after a release of tritium had occurred, perhaps during maintenance of some part of the reactor system. They also note that during the time period in question (1986 to 1989), three additional reactors had come on-stream at the Pickering complex. In addition, they have found that tritium levels during 1990 were down from those recorded in 1989, probably because tritium is now extracted at the plant site and is sold as a commercial product. It is used in the manufacture of such products as airport runway lights. Despite these reassurances from Ontario Hydro, there are

those who find the situation alarming, and who feel that the potential health effects of tritium are underestimated. The Ontario Ministry of Environment intends to continue monitoring the situation.

4. Ongoing Safety Concerns at Pickering Station: December 1994 - Present

In December 1994, a pipe connecting a pressure valve to an overflow tank cracked as a result of excessive vibrations. The crack allowed heavy water to leak out of the reactor and into a sump tank, which then overflowed, spilling 140,000 to 150,000 litres of radioactive water into the reactor building. None of the water was released to the environment but, as a result of the accident, all four of the units in Pickering A were shut down. In its investigation of the accident, the Atomic Energy Control Board (AECB) discovered a basic design flaw in the pressure release valves. The three units not affected by the accident were allowed to return to service, but it took one year and $12 million for Ontario Hydro to re-design and re-install the new system in unit 2, which remained closed until December 1995. The same new system was also put into the other three units.

In September 1995, the AECB threatened to close Pickering station again. This time the threat came as a result of what the Board called "a significant number of serious events," including the above-noted incident and others in which workers had botched maintenance jobs (for example, adjusting the backup safety systems on the wrong reactors and leaving two reactors without a backup for several hours). The AECB was sharply critical of the plant operators and has put them on notice that they must improve the safety mentality of the workers or face a shutdown. The Board noted that the problems appeared to be the attitude and motivation of the workers rather than deficient equipment. Some workers are blaming staff and budget cuts for the more relaxed approach to safety practices at the plant. The AECB continues to monitor the situation closely.

PARLIAMENTARY ACTION

On 21 March 1996, the federal government introduced Bill C-23, An Act to establish the Canadian Nuclear Safety Commission and to make consequential amendments to other Acts. This Act would, for the first time, separate the legislative authority for research and development of nuclear power from the regulation of nuclear safety. The name of the Atomic Energy Control Board (AECB) would be changed to the Canadian Nuclear Safety Commission (CNSC). This would allow for a clearer distinction between Atomic Energy of Canada Limited (AECL) and its regulator (AECB).

The new Act would give the CNSC the specific legislative authority that the AECB currently exercises under a very general clause in the existing *Atomic Energy Control Act*. The Act would also allow the provinces to enforce certain aspects of operation of nuclear plants which fall within their jurisdiction. At present, these activities are technically the responsibility of the federal government, because the Act is all-inclusive and covers every activity at a nuclear facility, even health regulations in the cafeteria.

Bill C-23 has received second reading and was referred to the House of Commons Standing Committee on Natural Resources on 12 June 1996. The Committee is expected to deal with the bill in the fall session of Parliament.

CHRONOLOGY

1 August 1983 - An abrupt pressure tube failure occurred at Pickering-2. This was the first major failure in the primary cooling system of a CANDU reactor. The unit was shut down for re-tubing.

14 November 1983 - Pickering-1 was shut down for examination of its pressure tubes for hydrogen buildup.

7 March 1984 - Ontario Hydro announced that Pickering Unit 1 would also undergo a complete re-tubing.

26 April 1986 - An explosion and fire occurred in Unit 4 at the Chernobyl generating station in the USSR, destroying the reactor and releasing massive amounts of radiation from its core.

25 August 1986 - The International Atomic Energy Agency received and began to review an official Soviet report on the causes and effects of the Chernobyl accident. Gross human negligence was cited as the cause.

September 1986 - Canada signed two international conventions concerning nuclear safety. The first convention provides for early notification and information about nuclear accidents and the second commits signatories to help other nations which suffer a nuclear accident.

November 1986 - Construction of the concrete sarcophagus to entomb the destroyed Unit 4 at Chernobyl was completed. **Today, there is concern about the integrity of the sarcophagus and its replacement is seen as a priority.**

February 1991 - Unit 2 at the Chernobyl nuclear power station was damaged by fire. It has not been returned to service and is scheduled for permanent closure in 1996.

December 1994 - A pressure valve failure at Pickering caused a spill of up to 150,000 litres of radioactive water into the containment structure.

May 1996 - Ukrainian officials and representatives of the G-7 nations reached an agreement on the financing and timing for closure of the Chernobyl facility. Unit 2 would close permanently in 1996, Unit 1 in 1997, and Unit 3 (adjacent to the sarcophagus on the destroyed Unit 4) in 1999.

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